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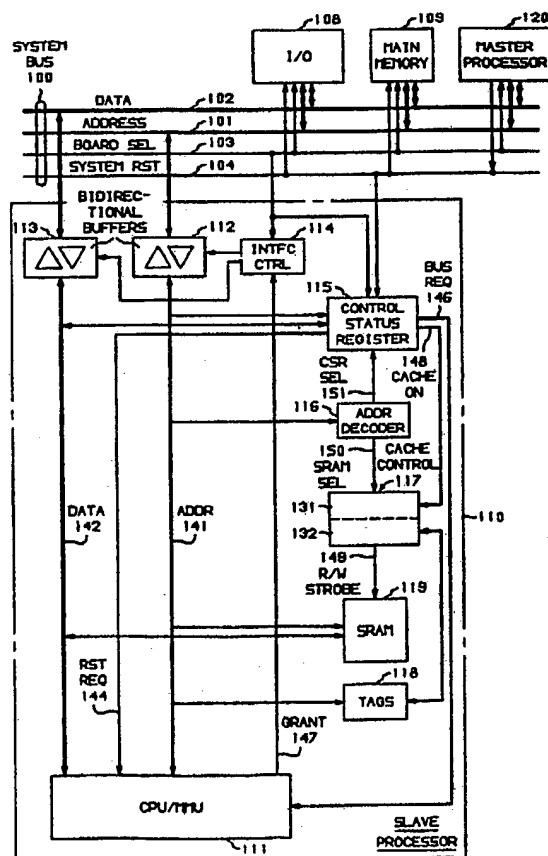


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(21) International Application Number: PCT/US87/02155 (22) International Filing Date: 25 August 1987 (25.08.87) (31) Priority Application Number: 048,151 (32) Priority Date: 11 May 1987 (11.05.87) (33) Priority Country: US (71) Applicant: AMERICAN TELEPHONE & TELEGRAPH COMPANY [US/US]; 550 Madison Avenue, New York, NY 10022 (US). (72) Inventors: CULLISON, Dennis, Lee ; 287 Westbrook Circle, Naperville, IL 60565 (US). WAGNER, Thomas, Andrew ; 3 S. 191 Brookside Court, Warrenville, IL 60555 (US). (74) Agents: HIRSCH, A., E., Jr. et al.; Post Office Box 679, Holmdel, NJ 07733 (US).		(81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent). Published <i>With international search report.</i>

(54) Title: MULTI-PURPOSE MEMORY**(57) Abstract**

In a master-slave multiprocessor, a slave processor (110) includes a random access memory array (119) that serves at initialization time as the slave processor's boot memory and that serves during normal operation time as the slave processor's cache memory. A master processor (120) writes the slave processor's boot program into the memory array when the memory array is to serve as the boot memory, i.e., following system reset.



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MULTI-PURPOSE MEMORY

Technical Field

The invention relates to processors in general and to memories of data processors in particular.

5 Background of the Invention

Today's typical processor includes special purpose memories provided to enhance ease of use and performance of the processor. Included among these memories are a boot memory--typically a read only memory
10 (ROM)--that stores a boot program whose execution by the processor's central processing unit (CPU) upon system power-up or reset automatically initializes the CPU, and a cache memory--implemented as a random access memory (RAM)--that serves during normal processor operation as a
15 high-speed buffer for information--illustratively either or both data and instructions--passing between the CPU and the processor's main on-line memory.

Storage devices used to implement such memories add to the cost of the processor, and also occupy valuable
20 circuit board space. The latter is especially a serious consideration in the case of single-board processors, where a whole processor is implemented on a single circuit board. In such processors, providing of such special-purpose memories may potentially be done only at the
25 sacrifice of some other processor capabilities, because circuit board space may not be available for circuitry needed to implement both.

Accordingly, it is a problem in the prior art to provide special-purpose memory functions in a processor
30 with the minimum number of memory devices so as to minimize processor cost and to occupy minimum circuit board space.

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Summary of the Invention

The invention is directed to solving these and other problems of the prior art. According to the invention, there is provided a memory that serves as
5 different special-purpose memories at different times. A control arrangement causes the memory at one time to serve a first function exclusive of a second function, and at another time to serve the second function exclusive of the first function. Specifically, an apparatus such as a
10 processor includes a processing unit, a memory coupled to the processing unit, and an arrangement coupled to the memory for selectively causing the memory: (a) to store at one time a boot program for execution by the processing unit at initialization, and (b) to buffer at another time
15 information passing between the processing unit and another memory during normal operation. The memory is thus caused to selectively serve as either a boot memory or a cache memory for the processing unit. The apparatus further includes means for effecting storage of the boot
20 program in the memory when the memory is serving as the boot memory. Illustratively, the apparatus is a multiprocessor wherein the processing unit and memory are parts of one processor and the means for effecting storage of the boot program in the memory is another processor.

25 Because the memory serves different functions at different times, separate memory devices need not be included in the system to implement each function. Rather, the functions are all implemented via the same memory device. Elimination of extra memory devices
30 beneficially lowers system cost and reduces the circuit board area occupied by memory devices.

These and other advantages and features of the present invention will become apparent from the following description of an illustrative embodiment of the invention
35 taken together with the drawing.

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Brief Description of the Drawing

FIG. 1 is a block diagram of a processing system that includes an illustrative embodiment of the invention; and

5 FIG. 2 flowcharts relevant portions of initializing operations of the master processor of FIG. 1.

Detailed Description

FIG. 1 shows a multiprocessor system. Illustratively, this system is the 3B2/600 computer of AT&T expanded into a master-slave multiprocessor configuration by connection thereto of a second processor. The original processor of the 3B2/600 computer functions as master processor 120 of the system. The added second processor functions as slave processor 110.

10 Illustratively, processor 110 is substantially a duplicate of processor 120, modified as described below. Slave processor 110 is connected to an input and output (I/O) slot of system bus 100 of the 3B2/600 computer. Illustratively, a main on-line memory 109 and an I/O subsystem 108 such as a disk are connected to other slots of system bus 100. Bus 100 connects units 108-110 to master processor 120 for communication.

System bus 100 includes an ADDRESS bus 101, a DATA bus 102, BOARD SELECT lines 103, and a SYSTEM RESET line 104.

Slave processor 110 includes a central processing unit (CPU) and memory management unit (MMU) 111. Illustratively, CPU/MMU 111 comprises the WE 32100 microprocessor chip set. CPU/MMU 111 is connected to ADDRESS bus 101 and DATA bus 102 through bidirectional tri-state buffers 112 and 113, respectively. DATA lines 142 connect CPU/MMU 111 to buffer 113 while ADDRESS lines 141 connect CPU/MMU 111 to buffer 112. Buffers 112 and 113 are under control of interface controller 114, which is connected to the one of the BOARD SELECT lines 103 that is associated with slave processor 110, and to CPU/MMU 111 via a GRANT line 147.

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Slave processor 110 also includes a control status register (CSR) 115. CSR 115 is connected to the one line of BOARD SELECT lines 103 that is associated with slave processor 110, and, in addition, is connected to
5 SYSTEM RESET line 104, DATA lines 142, ADDRESS lines 141, a RESET REQUEST line 144, a BUS REQUEST line 146, and a CACHEON line 148. Lines 144 and 146 connect CSR 115 with CPU/MMU 111.

Slave processor 110 further includes a static
10 random access memory (SRAM) array 119. SRAM array 119 is connected to ADDRESS lines 141 and DATA lines 142. SRAM array 119 is controlled by a cache controller 117 through a read and write (RW) strobe line 149.

As the name implies, cache controller 117
15 typically causes SRAM array 119 to function as a cache memory. Logically, cache controller 117 is divided into two control portions 131 and 132, each of which is active at different times and each of which causes SRAM array 119 to operate in a different mode. Control portion 132
20 causes array 119 to operate in conventional cache memory mode, as a virtual address-and-data cache memory for buffering information passing between CPU/MMU 111 and main memory 109. Control portion 132 is aided by a conventional tag memory 118 associated with array 119 and
25 communicatively connected to control portion 132. Tag memory 118 is also connected to ADDRESS lines 141. Control portion 131 causes array 119 to operate in "diagnostic" mode, wherein individual locations of array 119 may be addressed and read or written. Control
30 portion 131 is aided by a conventional address decoder 116. Decoder 116 is connected to control portion 131 by SRAM SELECT line 150, is connected to CSR 115 by CSR SELECT line 151, and is also connected to ADDRESS lines 141. Selection of which one of the two
35 control portions 131 and 132 is active and in control of array 119, and hence in which mode array 119 is operating, is made by CSR 115 via a CACHEON line 148.

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Operational aspects of the system of the FIG. 1 that are relevant to an understanding of the invention will now be described in conjunction with FIG. 2.

Upon system power-up or re-initialization,

5 master processor 120 pulses (momentarily asserts) SYSTEM RESET line 104, at step 200. This action sets a RESET bit and a HALT bit of CSR 115. Setting of the HALT bit leads CSR 115 to assert BUS REQUEST line 146. Setting of the RESET bit leads CSR 115 to assert RESET REQUEST line 144.

10 CPU/MMU 111 responds to assertion of RESET REQUEST line 144 by resetting slave processor 110, including clearing certain bits in CSR 115, in particular the RESET bit and a CACHEON bit. Clearing of the RESET bit and the CACHEON bit causes CSR 115 to deassert RESET

15 REQUEST line 146 and CACHEON line 148. CPU/MMU 111 responds to the request signal on BUS REQUEST line 146, which indicates the highest priority request for access to ADDRESS and DATA lines 141 and 142, by asserting GRANT line 147 and by stopping further activities. CPU/MMU 111

20 then waits for BUS REQUEST line 144 to be deasserted.

Following its momentary assertion of SYSTEM RESET line 104, master processor 120 retrieves a boot program for initializing CPU/MMU 111 from either main memory 109 or secondary memory--disk--of I/O

25 subsystem 108, at step 201, and effects storage of the program in SRAM 119, at step 202. Illustratively, it does so as follows.

After it has retrieved an instruction of the boot program from memory, master processor 120 asserts the

30 line of the BOARD SELECT lines 103 that is associated with slave processor 110, places an address of the address spectrum of SRAM array 119 at which the instruction is to be stored on ADDRESS bus 101, and places the instruction on DATA bus 102.

35 Assertion of slave processor's BOARD SELECT line 103 while GRANT line 147 is asserted causes interface control 114 to open buffers 112 and 113 thereby to

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transfer the information from ADDRESS and DATA buses 101 and 102 onto ADDRESS and DATA lines 141 and 142, respectively. Address decoder 116 examines the address appearing on ADDRESS lines 141. When it detects an
5 address lying within the address spectrum of SRAM array 119, it asserts SRAM SELECT line 150.

Cache control portion 131 responds to signals on SRAM SELECT line 150 while CACHEON line 148 is deasserted, by issuing a strobe signal to SRAM array 119 via R/W
10 strobe line 149. SRAM array 119 responds to the strobe signal by storing the instruction conveyed by DATA lines 142 in the location addressed by ADDRESS lines 141.

This process is repeated until master processor 120 has stored the whole boot program in SRAM
15 array 119. Master processor 120 then accesses and writes CSR 115 to reset the HALT bit, at step 203, in the same manner as it writes SRAM array 119. Address decoder 116 recognizes the address generated by master processor 120 as being an address of CSR 115. Address decoder 116
20 therefore asserts CSR SELECT line 151 to cause CSR 115 to respond to the address and data appearing on ADDRESS lines 141 and DATA lines 142, respectively. The response of CSR 115 thereto is to reset its HALT bit and, consequently, to deassert BUS REQUEST line 146.

25 Deassertion of BUS REQUEST line 146 causes CPU/MMU 111 to continue its normal operation. Following reset, this operation involves initialization, which begins by execution of a boot program stored beginning at a predetermined address in memory. This address is set to
30 be the SRAM array 119 address at which the boot program begins. Accordingly, CPU/MMU 111 generates an SRAM array 119 address on ADDRESS lines 141. This address is recognized as an SRAM array 119 address by address decoder 116, which responds by asserting SRAM SELECT
35 line 150. CACHEON line 148 is still deasserted, so cache control portion 131 is active, and it responds to assertion of SRAM SELECT line 150 by issuing a strobe to

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SRAM array 119 on R/W strobe line 149. SRAM array 119 responds to the strobe signal by outputting on DATA lines 142 the instruction stored at the address appearing on ADDRESS lines 141. CPU/MMU 111 then receives the
5 instruction over DATA lines 142 and executes it. This cycle is repeated until CPU/MMU 111 completes execution of the boot program. Hence, SRAM array 119 serves as the boot memory for CPU/MMU 111.

Having been booted, CPU/MMU 111 can now begin to
10 access and execute programs from main memory 109. These may be further initialization programs, for example. Upon completion of initialization, when CPU/MMU 111 is about to enter normal operating mode including virtual addressing mode, CPU/MMU 111 sets the CACHEON bit of CSR 115.
15 CPU/MMU 111 accesses the CSR 115 by generating the address of CSR 115 on ADDRESS lines 141. The address is recognized by address decoder 116, which asserts CSR SELECT line 151 in response. CSR 115 responds to
assertion of CSR SELECT line 151 by allowing CPU/MMU 111 a
20 write access to CSR 115 via the ADDRESS and DATA lines 141 and 142.

CSR 115 responds to setting of the CACHEON bit by asserting CACHEON line 148. Assertion of CACHEON line 148 disables cache control portion 131, so that it no
25 longer responds to assertions by address decoder 116 of SRAM SELECT line 150, and enables cache control portion 132 to control SRAM 119. As was mentioned above, control portion 132 causes SRAM 119 to function as a virtual data-and-instruction cache memory for CPU/MMU 111,
30 in a conventional manner. Upon being enabled, control portion 132 initializes the cache by flushing, that is, invalidating, its contents.

Henceforth, the system of FIG. 1 functions conventionally, until the next time that system reset
35 line 104 is asserted. At that time, the operations described herein are repeated.

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Of course, various changes and modifications to the illustrative embodiment described above will be apparent to those skilled in the art. For example, the system of FIG. 1 may include more than one slave processor 110. Or, the system may be a uniprocessor, wherein the multi-purpose memory of the single processor is loaded with the boot program by some other system unit, such as an I/O controller. Also, other functions, such as scratch memory functions, may be included among the functions of the multi-purpose memory. Such changes and modifications can be made without departing from the spirit and the scope of the invention and without diminishing its attendant advantages. It is therefore intended that such changes and modifications be covered by the following claims.

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Claims

1. An apparatus (FIG. 1) including a memory (119) and equipment coupled to the memory, characterized in that the equipment includes:

5 means (115-118, 120) for causing the memory at one time to serve a first function exclusive of a second function, and for causing the memory at another time to serve the second function exclusive of the first function.

2. The apparatus of claim 1 wherein the
10 equipment includes a processor (111) and a second memory (109) coupled to the processor, characterized in that the means comprise

means (115-118, 120) for causing the one memory at one time to store an initialization program for
15 execution by the processor, and at another time to buffer information passing between the processor and the second memory.

3. The apparatus of claim 1 wherein the equipment includes a processor (111), characterized in
20 that the means comprise

means (115-118) for selectively causing the memory to serve as one of (a) a boot memory for the processor and (b) a cache memory for the processor; and

means (120) for effecting storage in the memory
25 of a boot program for the processor when the memory is serving as a boot memory.

4. The apparatus of claim 1 wherein the equipment includes a processor (111), characterized in that the means comprise

30 means (115-118, 120) for causing the memory at one time to serve as a boot memory for the processor and at another time to serve as a cache memory for the processor.

5. The apparatus of claim 4 characterized in
35 that the means include

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means (120) for effecting storage in the memory of a boot program for the processor when the memory is serving as a boot memory.

6. The apparatus of claim 4 characterized in
5 that the means include

first means (116, 131) coupled to the memory, when activated for causing the memory to function as a boot memory for the processor,

second means (113, 132) coupled to the memory,
10 when activated for causing the memory to function as a cache memory for the processor, and

third means (115) connected to the first and the second means, for selectively activating one of the first and the second means while deactivating the other of the
15 first and the second means.

7. The apparatus of claim 6 wherein the causing means further include

a second processor (120) for causing the third means to activate the first means and for effecting
20 storage in the memory of a boot program for the processor while the first means are activated.

8. A method of operating a memory (119), characterized by the steps of:

activating a first memory control means (131)
25 and deactivating a second memory control means (132), in response to receipt of a first signal;

operating the memory in a first mode of operation under control of the active first memory control means, wherein the memory serves a first function
30 exclusive of a second function;

deactivating the first memory control means and activating the second memory control means, in response to receipt of a second signal; and

operating the memory in a second mode of
35 operation under control of the active second memory control means, wherein the memory serves the second function exclusive of the first function.

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9. The method of claim 8 characterized in that the memory functions as a boot memory in the first mode of operation; and

the memory functions as a cache memory in the
5 second mode of operation.

10. The method of claim 9 characterized in that the step of operating the memory in the first mode of operation comprises the step of:

storing (FIG. 2) a boot program in the memory.

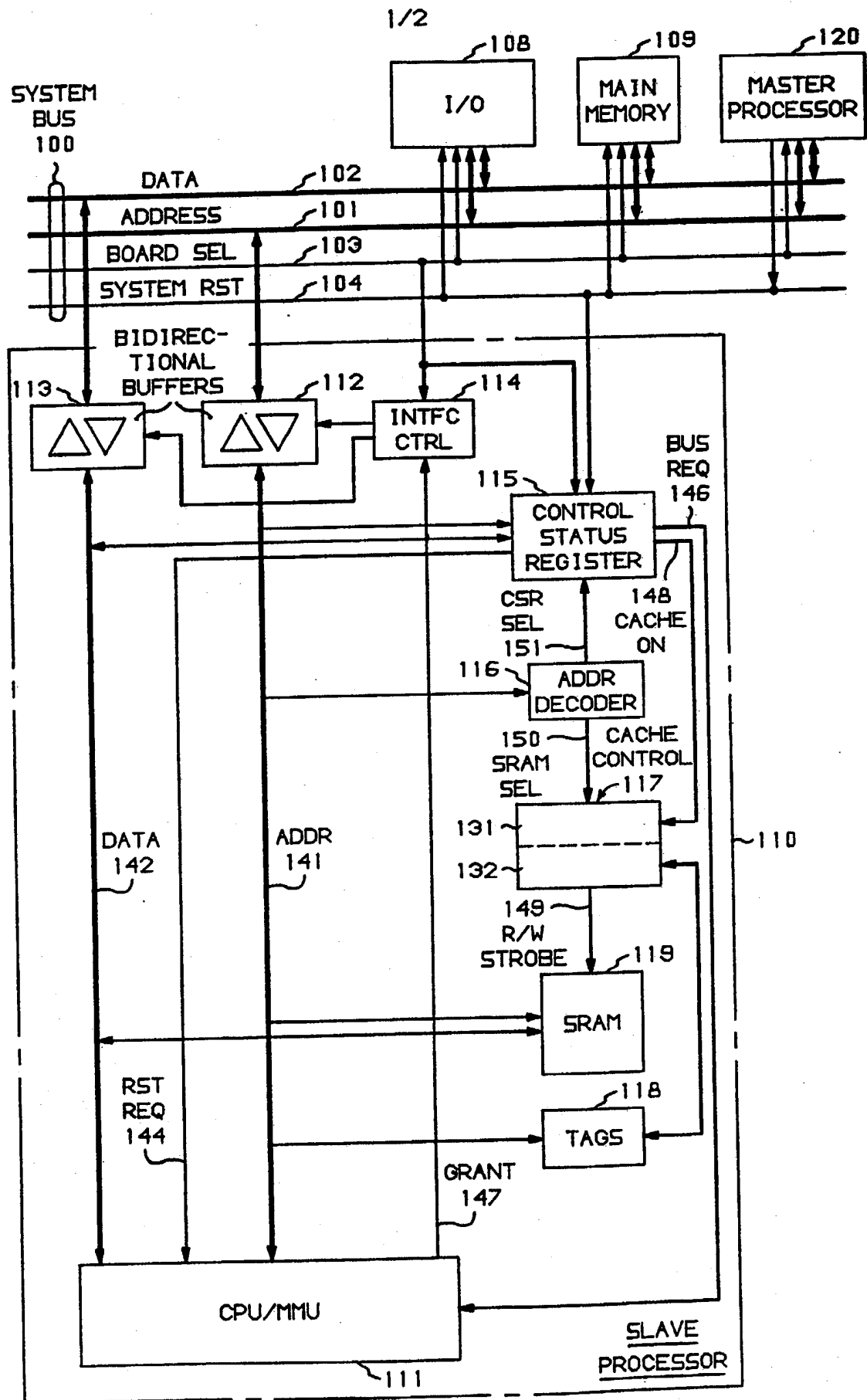
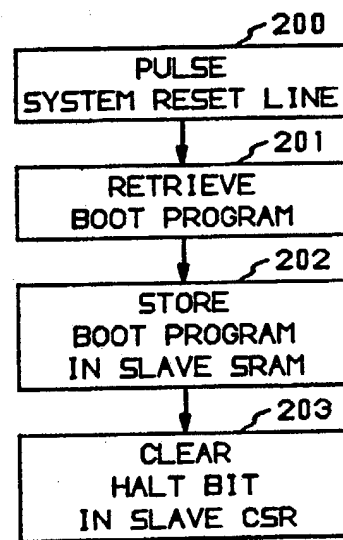


FIG. 1

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FIG. 2



INTERNATIONAL SEARCH REPORT

International Application No PCT/US 87/02155

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶ According to International Patent Classification (IPC) or to both National Classification and IPC IPC ⁴ : G 06 F 9/44; G 06 F 12/08														
II. FIELDS SEARCHED <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black; margin: 5px 0;">Minimum Documentation Searched ⁷</div> <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 25%; border-bottom: 1px solid black;">Classification System</th> <th style="border-bottom: 1px solid black;">Classification Symbols</th> </tr> <tr> <td style="border-right: 1px solid black; padding: 5px;">IPC⁴</td> <td style="padding: 5px;">G 06 F 9/00; G 06 F 12/00</td> </tr> </table> <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black; margin: 5px 0;">Documentation Searched other than Minimum Documentation to the extent that such Documents are included in the Fields Searched ⁸</div>			Classification System	Classification Symbols	IPC ⁴	G 06 F 9/00; G 06 F 12/00								
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III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹ <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 10%; border-bottom: 1px solid black;">Category ⁹</th> <th style="border-bottom: 1px solid black;">Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²</th> <th style="width: 15%; border-bottom: 1px solid black;">Relevant to Claim No. ¹³</th> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">X</td> <td style="padding: 5px;">IBM Technical Disclosure Bulletin, volume 21, no. 10, March 1979, (New York, US), R.J. Gallagher: "Read-only storage/random-access memory mode change", pages 4100-4101 see the whole document</td> <td style="text-align: center; vertical-align: top; padding: 5px;">1,8</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="text-align: center; vertical-align: top; padding: 5px;">--</td> <td style="text-align: center; vertical-align: top; padding: 5px;">2-6,9,10</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">IBM Technical Disclosure Bulletin, volume 20, no. 10, March 1978, (New York, US), S.G. Hogan et al.: "Loading and running a program without main storage", page 4032 see the whole document -----</td> <td style="text-align: center; vertical-align: top; padding: 5px;">1-6,8-10</td> </tr> </table>			Category ⁹	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³	X	IBM Technical Disclosure Bulletin, volume 21, no. 10, March 1979, (New York, US), R.J. Gallagher: "Read-only storage/random-access memory mode change", pages 4100-4101 see the whole document	1,8	A	--	2-6,9,10	A	IBM Technical Disclosure Bulletin, volume 20, no. 10, March 1978, (New York, US), S.G. Hogan et al.: "Loading and running a program without main storage", page 4032 see the whole document -----	1-6,8-10
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<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>¹⁰ Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"A" document member of the same patent family</p> </div> </div>														
IV. CERTIFICATION <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; border-bottom: 1px solid black; padding: 5px;">Date of the Actual Completion of the International Search</td> <td style="width: 50%; border-bottom: 1px solid black; padding: 5px;">Date of Mailing of this International Search Report</td> </tr> <tr> <td style="text-align: center; padding: 5px;">18th January 1988</td> <td style="text-align: center; padding: 5px;">22 FEB 1988</td> </tr> <tr> <td style="border-bottom: 1px solid black; padding: 5px;">International Searching Authority</td> <td style="border-bottom: 1px solid black; padding: 5px;">Signature of Authorized Officer</td> </tr> <tr> <td style="text-align: center; padding: 5px;">EUROPEAN PATENT OFFICE</td> <td style="text-align: center; padding: 5px;"> P.E.G. VAN DER PUTTEN </td> </tr> </table>			Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	18th January 1988	22 FEB 1988	International Searching Authority	Signature of Authorized Officer	EUROPEAN PATENT OFFICE	 P.E.G. VAN DER PUTTEN				
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